MEMORANDUM

To: Scott Golbek, PE (WSDOT)
From: Yong Zhu, PE (H.W. Lochner, Inc)

RE: Impact Attenuator Selection for VMS location
C9247 – South Union Gap Interchange – Construct Ramps Project.

References:
Chapter 2, Section 2.11.3.3 Impact Attenuators
Chapter 2, Section 2.11.4.4 Impact Attenuator Technical Memorandum
Plan sheets
Manufacturer's Information: REACT 350 and Quadguard II
July 2014 Design Manual Section 1620: Impact Attenuator Systems

Purpose and Need:
In accordance with Chapter 2, Section 2.11.3.3, of the Contract, the Design Builder is required to submit an Impact Attenuator Technical Memorandum when using a system other than the Owner-preferred REACT 350

The Design-Builder is proposing the Quadguard II impact attenuator. This is an approved QPL product included in the Impact Attenuator section of the Design Manual for the South Union Gap Interchange project.

Background:
Location: The project requires placement of new VMS signs with Monotube support structure to be placed in the median of I82. The placement of the monotube sign, both in the conceptual plans and as confirmed by WSDOT is near the existing HMA median crossover at approx. MP 37.00. The precise placement of the monotube base is 37 feet south of the median crossover.

The owner-preferred option, REACT 350, requires over 60 feet of space to accommodate the attenuator as well as the necessary transition sections. (The concrete pad for attenuator is 31'7" long. The transition section from the end of the attenuator is an additional 30 feet.)

There is not sufficient room to place the REACT 350 between the HMA crossover and the monotube structure.

Alternatives and Recommnedation

The proposed substitution is the Quadguard II impact attenuator. The Quadguard II is a 10' long, reusable, redirective, non-gating crash cushion for hazard protection, ranging in width from 24" to 120". It consists of energy-absorbing cartridges surrounded by a framework. The Quadguard II is listed in Chapter 1620 of the WSDOT Design Manual has been on the WSDOT approved QPL list since 2014. The

Quadguard 2 is a QPL approved system which meets the geometry requirements of the project. See DM information in the appendix of this memo.

The other alternative would include relocating the median crossover. Consultation between WSDOT and the Design-Builder determined this option could require several months to a year to complete and include numerous WSDOT and outside Agencies for input and guidance. As a QPL approved standard exists to meet the needs of the project, this alternative was not chosen.

Conclusion/Rationale: Quadguard II impact attenuator is shorter(10' vs 29') and wider (8' vs 3') than the React 350. It can be used more efficiently protecting wider objects such as VMS foundation and control cabinets. Especially, due to the shorter installation length, the existing median turnaround area will be maintained without modification and a FHWA review will not be needed.

Each approach end of concrete barrier shall be treated with an impact attenuator on the approved QPL list, that may include the trailing ends due to the roadway geometrics if deemed necessary by the Project Engineer, or offset out of design clear zone.

If concrete barriers are constructed back-to-back and the space between is 8 feet or less, the space shall be capped in accordance with the *WSDOT Standard Plans*.

Concrete barriers, barrier integral to, or embedded cast-in-place barriers shall be installed to mitigate clear-zone hazards associated with retaining walls and bridge piers.

Cable barrier terminals shall stand as an independent system and shall not be anchored to any guardrail or concrete barrier.

The Design-Builder shall include all guardrail transitions between existing guardrail and new guardrail installations.

2.11.3.2.1 *Walls and Barriers Along Right of Way*

Where there is a retaining wall or a noise wall along the Right of Way within 12 feet of vehicle access such as parking, driveways, or streets, the Design-Builder shall provide a concrete barrier to prevent vehicles from going over the top of the wall, to protect the wall from damage, and to redirect errant vehicles.

Where the top of a concrete barrier is below the top of a retaining wall or noise wall, the concrete barrier shall be placed as close to the wall as possible, and any gaps between the concrete barrier and wall shall be filled with concrete to the top of the concrete barrier. Where the top of the concrete barrier is above the top of a retaining wall or noise wall, the concrete barrier shall be cast integral with the wall, constructed on a moment slab, or offset a minimum of 2 feet from any part of the wall, coping, or cap.

Where the top of the concrete barrier and wall are less than 6 feet above the ground on the community side of the wall, then Right of Way fencing shall also be provided. The fencing shall be mounted to the top of the concrete barrier or wall, whichever is taller, in a manner that prevents trash, leaves, or other debris from collecting between the fencing and the concrete barrier or wall.

2.11.3.3 Impact Attenuators

All impact attenuators shall be approved by QPL and shall be designed in accordance with the *WSDOT* Design Manual. The WSDOT South Central Region maintenance preferred option is the React 350.

If the Design-Builder determines that the system referenced above does not meet the design requirements for the proposed application, the Design-Builder shall submit an *Impact Attenuator Technical Memorandum* to the WSDOT Engineer for Review and Comment prior to construction.

2.11.4.4 Impact Attenuator Technical Memorandum

The Design-Builder shall prepare and submit a technical memorandum to the WSDOT Engineer for Review and Comment when using a system other than the approved system from the QPL. The technical memorandum shall include the following:

- Attenuator location.
- Proposed substitution, including justification describing the attributes of the proposed attenuator that makes it the best product for the intended application.
- Specific design rationale describing why one of the systems referenced above is not applicable.

Acceptance will be at the WSDOT Engineer's sole discretion.

The design and written justification shall be revised based on comments received during the WSDOT Engineer Review and Comment.

2.11.4.5 Clear Zone Inventory

The Clear Zone Inventory shall be completed prior to the start of construction and updated to reflect all changes from the Project. The Clear Zone Inventory shall be prepared using the *Clear Zone Inventory Form* (Appendix O) and Chapter 1600 of the *WSDOT* Design Manual. The Clear Zone Inventory shall be included within the Design Documentation Package (DDP).

2.11.4.6 Pedestrian Facilities Technical Summary

This Section is intentionally omitted.

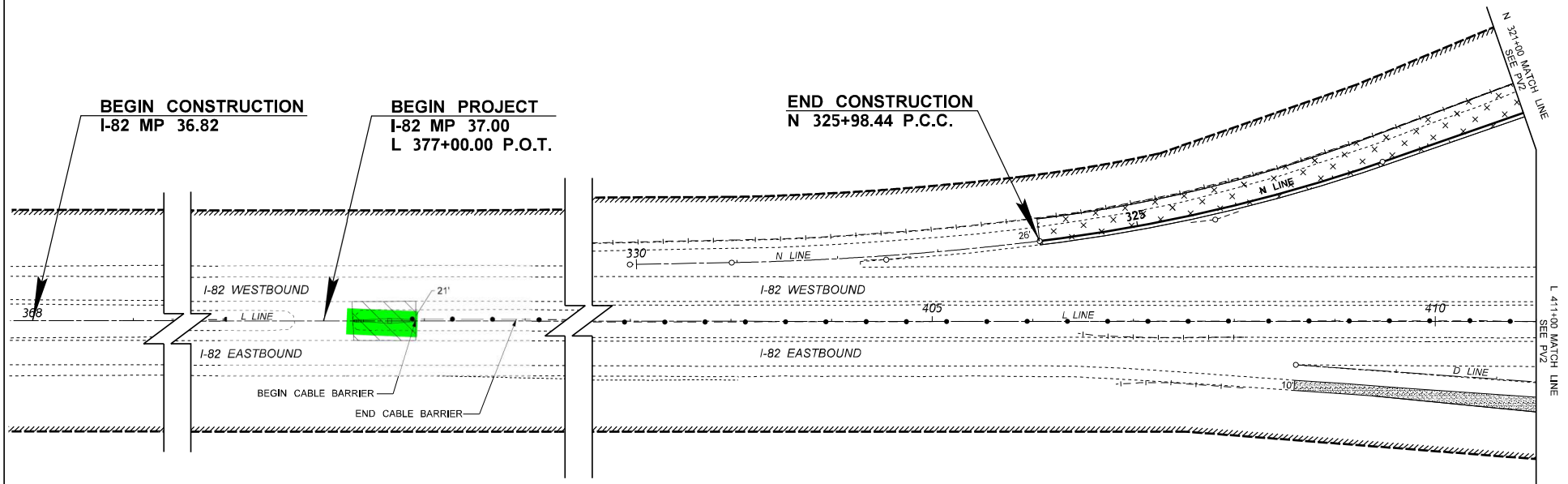
2.11.5 *Miscellaneous Submittals*

The Design-Builder shall deliver to the WSDOT Engineer Work-related submittals that do not fit in the previous categories, but are prepared in accordance with this Section.

End of Section

LEGEND

- ROADWAY SECTION A
- ROADWAY SECTION B
- ROADWAY SECTION C
- ROADWAY SECTION D
- ROADWAY SECTION E
- CABLE BARRIER
- PERMANENT IMPACT ATTENUATOR
- EXISTING CABLE BARRIER
- EXISTING GUARDRAIL



GENERAL NOTE:

1. FOR LANE AND SHOULDER WIDTHS, SEE PAVEMENT MARKING PLANS.

0 50 100
SCALE IN FEET

CONCEPTUAL DESIGN NOT FOR CONSTRUCTION

FILE NAME	K:\452205\082\03750_South Union Gap IC\Design_CAD_Conceptual Plans for RFP\250-Paving\XL3001_PS_PV01.dgn								Plot 1
TIME	1:08:26 PM				REGION NO. 10	STATE WASH	FED.AID PROJ.NO.		PLAN REF NO PV1
DATE	7/30/2018								
PLOTTED BY	sohfai				JOB NUMBER				
DESIGNED BY	F. SOH								
ENTERED BY	D. OLSEN								
CHECKED BY	J. TRUDEAU				CONTRACT NO.		LOCATION NO.		
PROJ. ENGR.	B. HOOKER								
REGIONAL ADM.	T. TREPANIER	REVISION	DATE	BY					

P.E. STAMP BOX — DATE

P.E. STAMP BOX — DATE

Washington State Department of Transportation

I-82
SOUTH UNION GAP INTERCHANGE
CONSTRUCT RAMPS

PAVING PLAN

SHEET 22 OF 39 SHEETS

2.18.4.4.2 *Closed Circuit Television Control Cabinet*

The Design-Builder shall furnish and install the CCTV control cabinets and shall provide all necessary tools and equipment to connect the cabinets to the cameras, electrical source, and communications system.

2.18.4.4.3 *Access to Closed Circuit Television*

The Design-Builder shall provide access in accordance with the *WSDOT South Central Region Intelligent Transportation System Design Requirements* (Appendix T). Maintenance vehicles, such as bucket trucks, shall have the ability to back up adjacent to the CCTV structure for maintenance of the CCTV and shall have adequate access onto and off the roadway.

2.18.4.5 Variable Message Signs

The Design-Builder shall furnish and install a double sided VMS at approximately the following location(s):

- I-82, Milepost, 37.00, in the median

The Design-Builder shall furnish, install, and test the VMS structure, foundation, power, software, local control panel assembly, and all other ancillary equipment and components, to create a fully-functioning and operable VMS system.

The Design-Builder shall position the sign to achieve the optimum sight line and maximum visibility for the vehicles approaching the sign. The minimum visibility requirement shall be 1,000 feet. The Design-Builder shall consider the sign-viewing angle for the VMS location and install the VMS in accordance with manufacturer's recommendations and this Section.

WSDOT TMC personnel will remotely operate the messages on the signs.

The Design-Builder shall design the support structure in accordance with the requirements of the *WSDOT South Central Region Intelligent Transportation System Design Requirements* (Appendix T). The Design-Builder shall mount the VMS to the support structure. The new VMS shall not be mounted on or supported by roadway bridges.

The Design-Builder shall furnish and install the VMS, VMS controller cabinets and accessories in accordance with this Section and as required to make the VMS fully-functioning and operable. Installation shall be in accordance with this Section and the *WSDOT South Central Region Intelligent Transportation System Design Requirements* (Appendix T). The Design-Builder shall notify the WSDOT Engineer when installation and testing of the VMS hardware is complete, so that the WSDOT Engineer can verify VMS operations.

The Design-Builder shall supply all equipment and personnel needed to load, transport, and unload the VMS. The Design-Builder shall provide power to each VMS within 10 Calendar Days of delivery of the VMS, or house the VMS in a controlled atmosphere facility.

Crash Cushions

QuadGuard® II

TRINITY HIGHWAY

Ahead of the Curve™

QuadGuard® II

The QuadGuard® II consists of an engineered steel nose and crushable, energy absorbing cartridges surrounded by a framework of steel Quad-Beam™ panels. The system is NCHRP Report 350 Test Level 2 and Test Level 3 compliant as a re-directive, non-gating crash cushion. The Test Level 2 QuadGuard II is 25% shorter than the original QuadGuard measuring less than 10' (3 m). The Test Level 3 model is also nearly 3' (1 m), shorter in length than its predecessor. The QuadGuard II can be used to shield fixed objects of 24" to 126" wide (610 mm to 3.2 m) while using less than 19' in length (22' for the 126").

QuadGuard II, as a member of the QuadGuard family of crash cushions, utilizes many of the same components as the QuadGuard.

TRINITY HIGHWAY

LESS IS MORE

Features

- Self-supporting steel nose, custom cut-out available.
- Monorail guide stabilizers.
- Anchorage options include: asphalt, concrete, soil-drive pile.
- QuadGuard II has 25% less footprint for TL-2 and 3' less for TL-3 than original QuadGuard.
- High strength Quad-Beam panels.
- Needs no anchoring chains or tension cables.
- Compact, modular design accommodates speeds from 25 mph (40 km/h) to 70 mph (115 km/h).

Back-Up Structure and Attachments

- Simplified backups - Tension strut or concrete
- Bridge pier(s) and parapet(s)
- Square block(s)
- Temporary & permanent concrete barrier(s)
- Thrie-beam
- W-beam

Assembly and Maintenance

- 25% less footprint for TL-2 and 3' less for TL-3, reducing installation costs.
- Damaged cartridges contain debris and are easily replaceable.
- Monorail base eliminates need for anchoring chains/tension cables.
- QuadGuard II may be reusable after design impacts

An original ENERGY ABSORPTION product.

Distributed by:

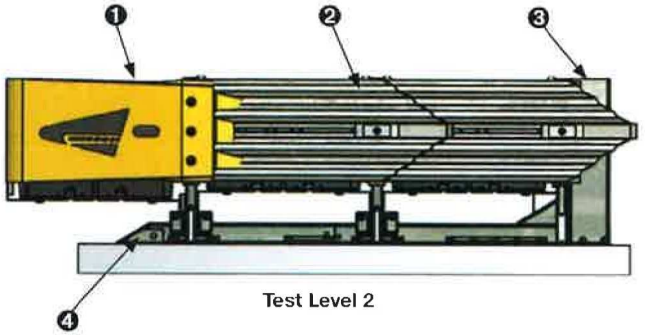
Specifications

Typical TL-2 Two-bay Unit
(Available in Widths of 24" 30", 36", 48"):

- 9'11" Long (3.03 m)
- 24" (610 mm) Min., 48" (1.22 m) Max. Width at backup structure.
- 1,210 lbs. (549 kg)

Typical TL-3 Five-bay Unit
(Available in Widths of 24", 30", 36", 69", 90", 126" (the 126" is a Six Bay Unit) Custom Widths):

- 19' Long (5.8 m)
- 24" (610 mm) Min., 126" (3.2 m) Max. Width at Backup Structure.
- 2,455 lbs. (1,114 kg)



Test Level 2

1. Engineered Steel Nose
2. Fender Panel
3. Steel Backup
4. Monorail

1-14

www.trinityhighway.com

1.888.323.6374

Chapter 1620 Impact Attenuator Systems

1620.01 General

Impact attenuator systems are protective systems that help aid an errant vehicle from impacting an object by either gradually decelerating the vehicle to a stop when hit head-on or by redirecting it away from the feature when struck on the side. These systems are used for rigid objects or other features that cannot be removed, relocated, or made breakaway.

Approved systems are shown in Exhibits 1620-1a and 1620-1b and on the Washington State Department of Transportation (WSDOT) Headquarters (HQ) Design Office web page:
www.wsdot.wa.gov/design/policy/roadsidesafety.htm

Approved systems shall meet standardized testing defined in National Cooperative Highway Research Program (NCHRP) Report 350 or the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (MASH). In addition, these devices shall have an acceptance letter from FHWA that certifies that the device meets the appropriate crash test criteria and is eligible for federal-aid reimbursement.

1620.02 Design Criteria

The following design criteria apply to new, existing, or reset permanent and temporary impact attenuators.

Impact attenuators are placed so that they do not present a feature that needs mitigating in relation to opposing traffic. For median and reversible lane locations, the backup structure or attenuator-to-object connection is designed to help in aiding opposing traffic from being snagged.

Avoid placement of curbs between attenuators and traffic. Refer to the specific attenuator manufacturer's instructions if considering placement of curbing between an attenuator and the travelled way. It is desirable that existing curbing be removed and the surface smoothed with asphalt or cement concrete pavement before an impact attenuator is installed. However, mountable curbs 4 inches or less in height may be retained depending on the feasibility of their removal.

In general, attenuators are aligned parallel to the roadway except the inertial barriers.

Consult with the Area Maintenance Superintendent who will be maintaining the system prior to selecting the attenuator systems to include in a construction contract.

1620.03 Selection

To select an appropriate impact attenuator system, the following factors must be assessed:

- Posted speed
- Operating speed
- Average daily traffic (ADT)
- Repair crew exposure
- Proximity to the roadway
- Anticipated number of yearly impacts
- Available space (length and width)
- Maintenance costs
- Initial cost
- Duration (permanent or temporary use)
- Portion of the impact attenuator that is redirective/nonredirective (see Exhibit 1620-2)
- Width of object to be shielded

It is very important for designers to take into account the portion of an impact attenuator that is designed to redirect vehicles during a side impact of the unit. It is crucial that fixed objects, either permanent or temporary (such as construction equipment), are not located behind the nonredirective portion of these devices.

The posted speed is a factor in the selection of many impact attenuators. Use Exhibits 1620-1a and 1620-1b to select the system and configuration appropriate for the posted speed. In the interest of a cost-effective design, selecting a system applicable for the posted speed is recommended (although using a system tested for a higher speed is acceptable). Where there is evidence that the average operating speed of the facility is higher than the posted speed, consider selecting an attenuator system rated at the facility's operating speed. Manufacturer's product information may indicate that a longer system (than what is in Exhibits 1620-1a and 1620-1b) is required for speeds of 70 mph or greater. These models are generally referred to as "high speed" or "70 mph" systems. Use of these systems on facilities with 70 mph posted speeds is not required, and selection of a system rated for at least 60 mph will typically be appropriate for most sites on these facilities. For permanent installations where unusual conditions warrant consideration of a high-speed device, these systems are available and may be used with justification. Contact the HQ Design Office for guidance when selecting one of these systems.

For a comparison summary of space and initial cost information related to impact attenuator systems, see Exhibits 1620-1a and 1620-1b.

When maintenance costs are considered, anticipate the average annual impact rate. If few impacts are anticipated, lower-cost devices such as inertial barriers might meet the need. (See Chapter 301 for examples of how to determine lifecycle costs for proposed hardware). Inertial barriers have the lowest initial cost and initial site preparation. However, maintenance will be costly and necessary after each impact. Labor and equipment are needed to clean up the debris and install new containers (barrels). Inertial barriers are not be used where flying debris might be a danger to pedestrians.

In selecting a system, one consideration is the anticipated exposure to traffic that the workers making the repairs may encounter. In areas with high traffic exposure, a low-maintenance system that can be repaired quickly is most desirable. Some systems need nearly total replacement or replacement of critical components (such as cartridges or braking mechanisms) after a head-on impact, while others simply need resetting.

It is very important to consider that each application is unique when selecting impact attenuators for use in particular applications. This applies to both permanent and temporary installations. When specifying the system or systems that can be used at a specific location, the list shown in Exhibits 1620-1a and 1620-1b are to be used as a starting point. As the factors discussed previously are analyzed, inappropriate systems may be identified and eliminated from further consideration. Systems that are not eliminated may be appropriate for the project. When the site conditions vary, it might be necessary to have more than one list of acceptable systems within a contract. Systems are not to be eliminated without documented reasons. Also, wording such as "or equivalent" is not to be used when specifying these systems. If only one system is found to be appropriate, then approval from the Assistant State Design Engineer of a public interest finding for the use of a sole source proprietary item is needed.

When a transition to connect with a concrete barrier, fixed object, or beam guardrail is needed (see impact attenuator descriptions in 1620.04), the transition type and connection may need to be specified. In most cases, the transition type and connection required will be a custom design per the manufacturer (these transitions are included in the cost of the impact attenuator). In a few cases, the transition type and connection to use will be as described in Chapter 1610 and the *Standard Plans* (these transition sections are not included in the cost of the impact attenuator and must be included as a separate bid item in the construction contract). Consult with the Area Maintenance Superintendent who will be maintaining the systems before finalizing the list of attenuators to be included in the contract.

1620.03(1) Low-Maintenance Category

The QuadGuard Elite, SCI100GM/SCI70GM, and REACT 350 are considered low-maintenance devices. These devices have a higher initial cost, requiring substantial site preparation, including a backup or anchor wall in some cases and cable anchorage at the front of the installation. However, repair costs are comparatively low, with labor typically being the main expense. Maintenance might not be needed after minor side impacts with these systems.

Installation of a low-maintenance device is desirable at locations that meet at least one of the following criteria:

- Sites with an ADT of 25,000 or greater
- Sites with a history/anticipation of more than one impact-per year
- Sites with unusually challenging conditions, such as limitations on repair time, a likelihood of frequent night repairs, or narrow gore locations

Document the decision in the DDP to use any device other than a low-maintenance device at locations meeting at least one of the criteria above.

Consider upgrading existing ADIEM, G-R-E-A-T, and Hex-Foam Sandwich impact attenuators to low-maintenance devices when the repair history shows one or more impacts per year over a three- to five-year period.

The HQ Design Office conducts an annual review of maintenance records to consider which devices should be included in the Low-Maintenance category. For a description of requirements that need to be met in order to be included in the Low-Maintenance category, see:
www.wsdot.wa.gov/publications/fulltext/design/roadsidesafety/low_maint.pdf

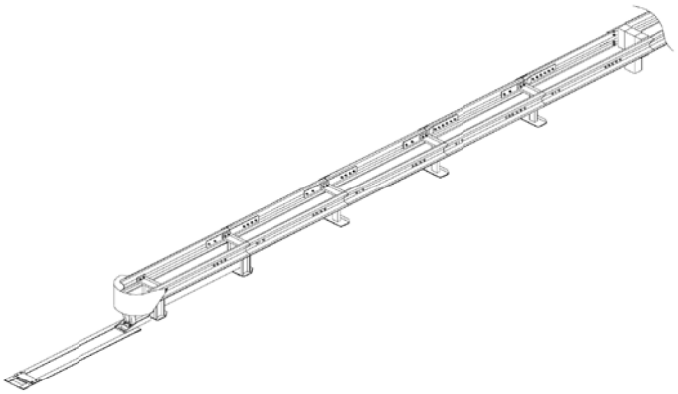
1620.04 Impact Attenuator Systems

1620.04(1) Permanent Installations

For systems used in permanent installations, a description of the system's purpose, parts, and function, as well as transition needs, foundation, and slope requirements are provided as follows and in Exhibits 1620-1a and 1620-1b.

1620.04(1)(a) Brakemaster 350

1. **Purpose:** The Brakemaster 350 system is an end treatment for W-beam guardrail and concrete barrier.
2. **Description:** The system contains an embedded anchor assembly, brake cable, W-beam fender panels, steel posts, tension and transition straps, and diaphragms.
3. **Function:** The system uses a brake and cable device for head-on impacts and for redirection. The cable is embedded in a concrete anchor at the end of the system.
4. **Foundation:** A concrete foundation is not needed for this system, but a paved surface is recommended.
5. **Slope:** 10H:1V or flatter slope between the edge of the traveled way and the near face of the unit.
6. **Transitions:** If used as an end treatment for concrete barrier, the system must be connected to the barrier with a transition section (not included in the cost of the attenuator). See Chapter 1610 and the *Standard Plans* for the type of transition section and connection required.
7. **Manufacturer/Supplier:** Energy Absorption Systems



Brakemaster 350 – Permanent Installations

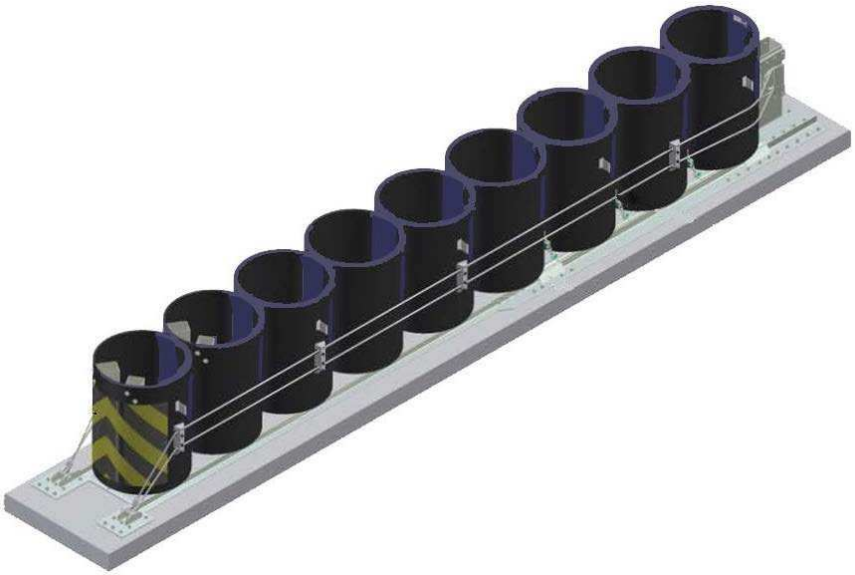
1620.04(1)(e) QuadGuard and QuadGuard II

1. **Purpose:** The QuadGuard and QuadGuard II provide end treatments for concrete barrier and beam guardrail. The QuadGuard can be used to mitigate fixed objects up to 10 feet wide and the QuadGuard II can be used to mitigate fixed objects up to 7 feet 6 inches wide.
2. **Description:** These systems consist of a series of Hex-Foam cartridges surrounded by a framework of steel diaphragms and quadruple corrugated fender panels. The QuadGuard and QuadGuard II use the same framework, but the QuadGuard II is shorter in length than the QuadGuard for any given posted speed.
3. **Function:** The internal shearing of the cartridges and the crushing of the energy absorption material dissipates impact energy from end-on hits. The fender panels redirect vehicles impacting the attenuator on the side.
4. **Foundation:** The systems are installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the QuadGuard and QuadGuard II.
6. **Transitions:** A transition section is not needed for concrete barrier and fixed objects exposed to traffic from only one direction. A custom transition section per manufacturer's specifications is needed for all connections to beam guardrail and for connection to a concrete barrier or fixed object exposed to bi-directional traffic (included in the cost of the attenuator).
7. **Manufacturer/Supplier:** Energy Absorption Systems

QuadGuard – Permanent and Work Zone Installations

1620.04(1)(i) Reusable Energy Absorbing Crash Terminal (REACT 350)

1. **Purpose:** The REACT 350 is an end treatment for concrete barriers and fixed objects up to 3 feet wide.
2. **Description:** The system consists of polyethylene cylinders with varying wall thicknesses, redirecting cables, a steel frame base, and a backup structure.
3. **Function:** The redirecting cables are anchored in the concrete foundation at the front of the system and in the backup structure at the rear of the system. When hit head-on, the cylinders compress, absorb the impact energy, and immediately return to much of their original shape, position, and capabilities. For side impacts, the cables restrain the system enough to help prevent penetration and redirect the vehicle. It is anticipated that this system will not need many replacement parts or extensive repairs following an impact.
4. **Foundation:** The system is installed on a concrete foundation.
5. **Slope:** If the site has excessive grade or cross slope, additional site preparation or modification to the units in accordance with the manufacturer's literature is needed. "Excessive" is defined as steeper than 8% for the REACT 350.
6. **Transitions:** Depending on traffic flow directions, the shape of the toe of the concrete barrier, and the ability to offset the system on the site, modifications to the toe of the concrete barrier and/or a custom transition section per manufacturer's specifications may be needed to prevent vehicle snagging (included in the cost of the attenuator).
7. **Manufacturer/Supplier:** Energy Absorption Systems



REACT 350 – Permanent and Work Zone Installations